Concealed conduction in left bundle of His

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The relation between heart rate, blocked P waves, and intraventricular conduction is analysed. The results indicate that concealed conduction in the left bundle engendered by a blocked P wave may result in left bundle-branch block in the following beat. The implications of this phenomenon are discussed in regard to (1) aberrant intraventricular conduction following a long RR interval, (2) absence of aberration when a short RR is preceded by a long one, and (3) the exceptions to the rule of bigeminy.

Aberrant intraventricular conduction following long RR intervals is a frequent finding in clinical electrocardiography. The recent discovery by Singer, Lazzara, and Hoffmann (1967) of the effect of phase '4' depolarization on intraventricular conduction has offered a reasonable explanation for this phenomenon. The purpose of the present study is to evaluate the possibility of an alternative explanation, that is impaired intraventricular conduction secondary to concealed discharge of the bundle-branches by a blocked atrial impulse.

Material and methods

A total of 941 cycle lengths recorded from a patient with sinus arrhythmia and multifocal supraventricular premature beats, single and in runs, was analysed to study the relation between rate and intraventricular conduction. Fig. 1 is a routine cardiogram recorded on this patient. Fig. 2 represents selected strips to demonstrate the mechanism involved. For purposes of analysis, 5 types of beats are identified: (a) beats with normal intraventricular conduction not preceded by a blocked P wave, (b) beats with left bundle-branch block not preceded by a blocked P wave, (c) beats with normal intraventricular conduction preceded by a blocked P wave, (d) beats with left bundle-branch block preceded by a blocked P wave, and (e) ventricular escapes. Fig. 3 shows the frequency distribution of these five types of beats in relation to the preceding RR interval.

Results

It is apparent from the observation of Fig. 3 that these 5 types of beats tend to occur at different heart rates. In order of progressively increasing RR intervals they can be grouped

as follows: (1) beats with left bundle-branch block without blocked P waves, (2) beats without left bundle-branch block without blocked P waves, (3) beats with left bundle-branch block preceded by blocked P waves, (4) beats without left bundle-branch block preceded by blocked P waves, and (5) ventricular escapes. This suggests that the occurrence of left bundle-branch block is not merely related to ventricular cycle length but also depends on the presence or absence of a preceding blocked P wave. This relation between blocked P waves and intraventricular conduction is best seen by analysis of the QRS complexes with RR intervals ranging between 0·73 and 0·82 sec which is the span of rate where the first 4 groups of beats noted above overlap (Table I). Left bundle-branch block occurred in 4 of the 24 beats without blocked P waves (17%) as compared to 12 of the 19 beats preceded by a

TABLE I *Number of beats with intervals from 0·73 to 0·82 sec, with and without preceding blocked P wave, with and without left bundle-branch block*

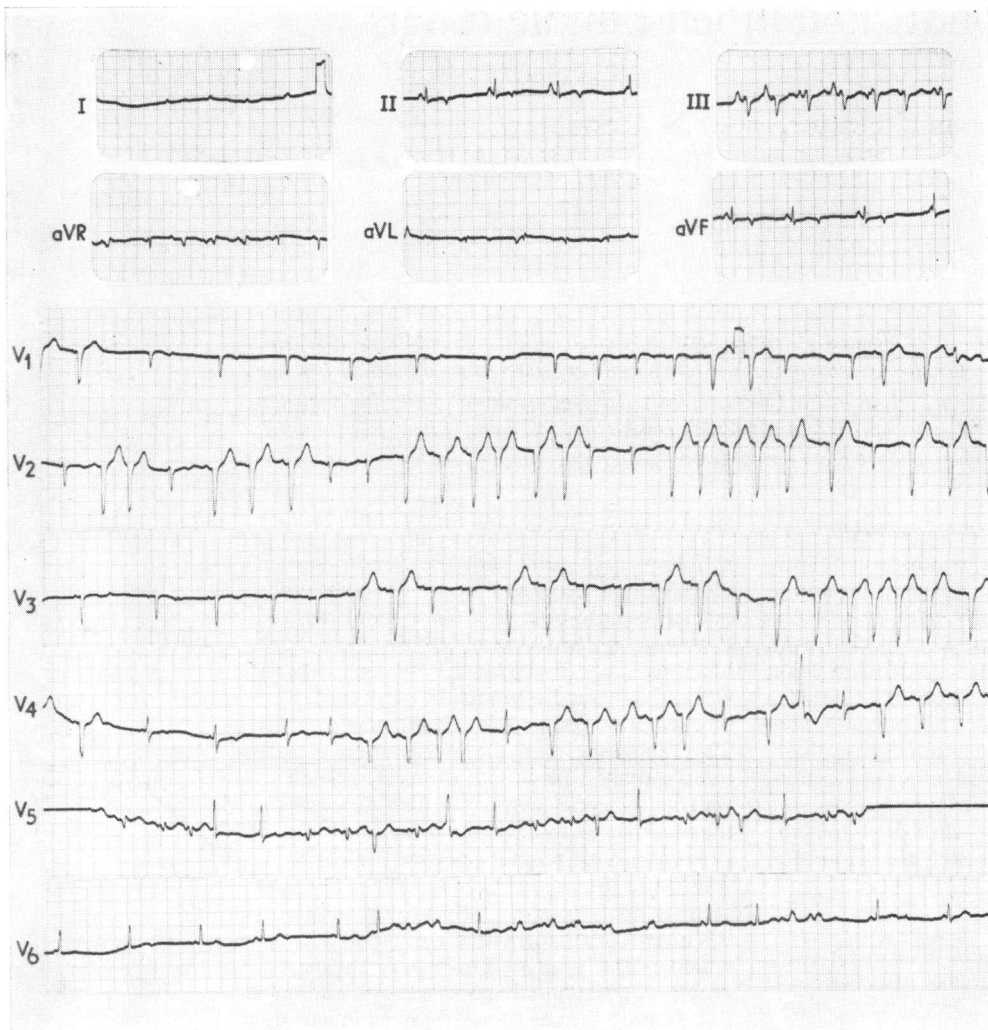|	With left bundle-branch block	Without left bundle-branch block	Total
Without blocked P	4	20	24
With blocked P	12	7	19
Total	16	27	43

FIG. I *Complete electrocardiogram showing intermittent complete left bundle-branch block and frequent atrial ectopic beats with varying atrioventricular and intraventricular conduction.*

blocked P wave (63%). The statistical significance of this difference in frequency is P <0·01. Therefore, the blocked P wave not only prolongs the RR interval but also has a separate effect on conduction in the left bundle of His.

Phase '4' depolarization is untenable as a possible explanation of left bundle-branch block in the beats following blocked P waves since normal conduction was invariably present at longer RR intervals. Equally untenable is the possibility that the complexes with left bundle-branch block are junctional beats with preferential conduction since retrograde P waves (entirely upright P waves in Lead CF$_1$) occurred only in 3 cases and all of them had normal intraventricular conduction.

Finally, AV dissociation with the lower pacemaker leading to abnormal intraventricular conduction cannot be the cause of the presence of left bundle-branch block in this group since the PR interval with antegrade P wave was no different in the group with normal conduction and with left bundle-branch block.

Since the occurrence of left bundle-branch block is rate-related it may be expected that the interval between the blocked P wave and the following QRS complex will be critical in determining the presence or absence of left bundle-branch block. To test this hypothesis, the beats preceded by a blocked P wave were analysed in relation to the interval between the blocked P wave and the following QRS
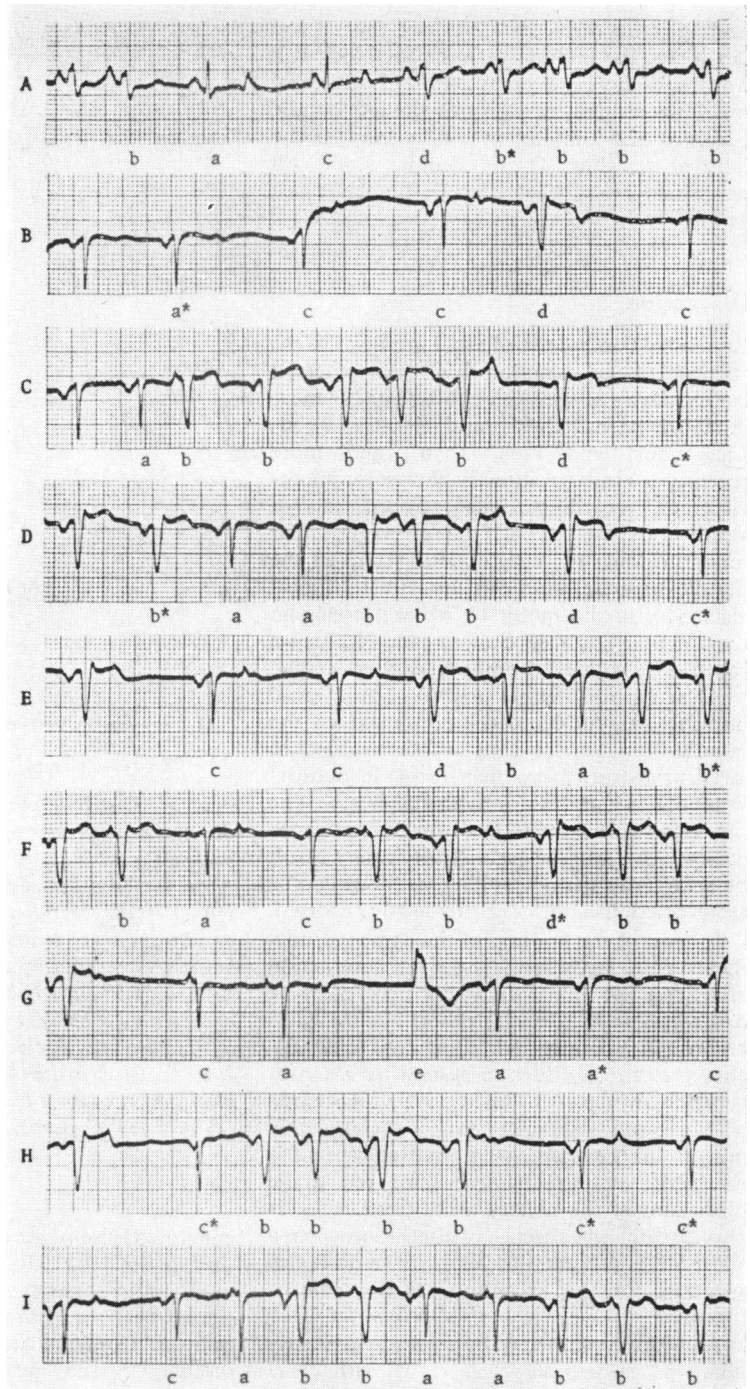
FIG. 2 *Rhythm strips showing examples of the five types of beats analysed (A = lead II, B to I = lead CF₁). a = beats with normal intraventricular conduction not preceded by a blocked P wave; b = beats with left bundle-branch block not preceded by a blocked P wave; c = beats with normal intraventricular conduction preceded by a blocked P wave; d = beats with left bundle-branch block preceded by a blocked P wave; and e = ventricular escapes. Note the variability of P wave morphology and duration and PR interval throughout these rhythm strips. The beats marked by an asterisk have short PR intervals without retrograde P waves and are suggestive of atrioventricular dissociation.*

complex (Table 2). This interval was 0·48 sec or less in 8 beats, 0·49 to 0·56 sec in 37, and greater than 0·56 sec in 85. Left bundle-branch block was present in 6 of the 8 beats with short PR intervals, in 9 of the 37 with intermediate intervals, and in none of the 85 with long PR intervals. These findings indicate that with a long interval between the blocked P wave and the QRS complex, even if penetration in the left bundle-branch had occurred, enough time would have elapsed for the left bundle to recover and for conduction to be normal. With shorter intervals between the blocked P wave and the QRS complex, if penetration in the left bundle had occurred, the time elapsed would have been too short for recovery and left bundle-branch block would result.

It may also be expected that the presence or absence of left bundle-branch block may be related to the interval between the preceding QRS complex and the blocked P wave. It would be possible, in fact, that with a long interval, penetration would be greater and with a short interval penetration would be less. A study of the beats in relation to the RP interval did not show any difference in regard to the conduction of the following beat. These

TABLE 2 *Number of beats preceded by a blocked P wave (Pb) with and without left bundle-branch block*

Pb-R interval	With left bundle-branch block	Without left bundle-branch block	Total T
≤0·48 sec	6	2	8
0·49–0·56 sec	9	28	37
>0·56 sec	0	85	85
Total	15	115	130

findings, therefore, indicate that the critical factor was the interval between the blocked P wave and the QRS complex: If the interval was long enough, recovery of the left bundle occurred and conduction was normal; if the interval was short, the left bundle would still be refractory and left bundle-branch block would result.

Discussion

Concealed conduction of atrial impulses in the atrioventricular junction has been inferred from analysis of surface cardiograms for more than 46 years (Lewis and Master, 1926; Langendorf and Pick, 1956), and more recently it has been directly shown by micro-electrode recordings. Also, penetration of atrial impulses beyond the atrioventricular junction down the conduction system in the bundle-branches has been shown with micro-electrodes in the rabbit by Moore (1966), in the dog by Myerburg, Stewart, and Hoffmann (1970), and with His bundle recordings in man by Narula and Samet (1970). Since atrial impulses, therefore, can be blocked in the bundle-branches, it is conceivable that blocked atrial premature beats may result in bundle-branch block in the subsequent beats. The cardiograms illustrated in this paper appear to indicate that bundle-branch block may result by such a mechanism, which, as far as can be ascertained, has not been previously reported.

In view of the findings of the present study, therefore, delayed intraventricular conduction after long RR interval may not necessarily be due to phase '4' depolarization but may also be brought about by preceding concealed discharge of the conduction system by a supra-ventricular impulse. This concealed discharge of the bundle-branches may be completely missed in the cardiogram in the case of a junctional premature beat with retrograde block and in the case of atrial fibrillation. It also explains the absence of aberration when a short RR is preceded by a long one and it also accounts for the exceptions to the rule of bigeminy.

Aberrant conducted beats are frequently noted in cardiograms, especially with atrial fibrillation, and, classically, aberrant conduction may be expected when a short RR interval is preceded by a long one. With a long interval the refractory period after the second ventricular complex is long and therefore the third ventricular depolarization may occur at a time when one of the bundles may still be refractory with resultant bundle-branch block. Exceptions to this rule can be explained by
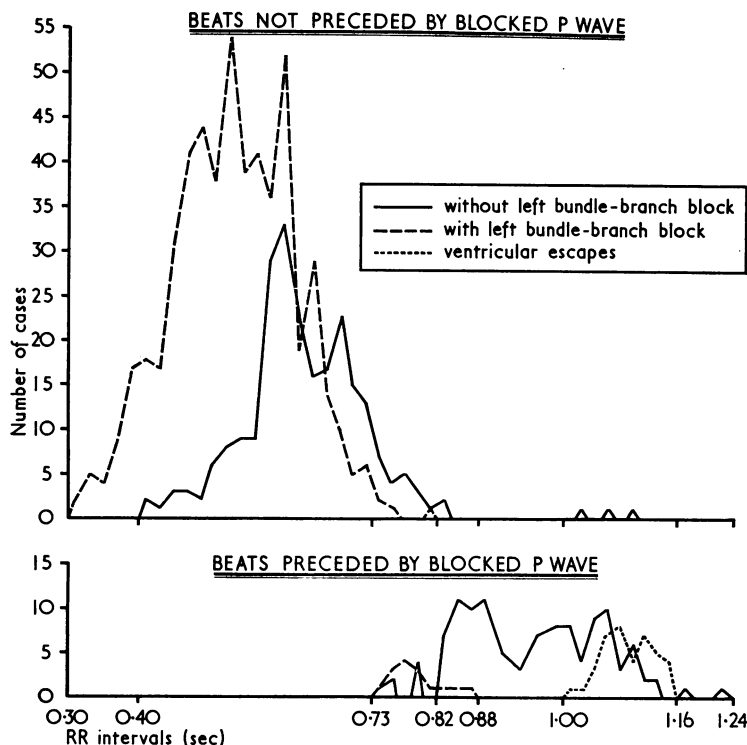

FIG. 3 *Distribution of various QRS patterns in relation to preceding RR intervals and presence or absence of blocked atrial beats. Note that in order of progressively increasing RR intervals the following types of beats can be identified. (1) Beats with left bundle-branch block not preceded by a blocked P wave, (2) beats without left bundle-branch block not preceded by a blocked P wave, (3) beats with left bundle-branch block preceded by a blocked P wave, (4) beats without left bundle-branch block preceded by a blocked P wave, and (5) ventricular escapes.*

concealed discharge of the bundle-branches during the long RR interval; this discharge may result either from a blocked AV junctional beat or from penetration of atrial impulses from fibrillating atria. The concealed discharge would shorten the refractory period of the second beat, so permitting normal conduction of the third.

Similarly, the exceptions to the rule of bigeminy, namely, the absence of a premature ventricular contraction after a long RR interval in atrial fibrillation (Langendorf, Pick, and Winternitz, 1955) could be explained by the presence of concealed discharge of the conduction system during the long cycle length.

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